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(54) IMPROVEMENTS IN KNEE JOINT PROSTHESES

(71) We, HERBERT KAUFER, LARRY STANFORD MATTHEWS, DAVID ANSEL SONSTEGARD, all citizens of the United States of America, and IAN PHILIP MURRAY, a British Subject, respectively of 601 Dartmoor; 1609 South University and 1725 Tudor Drive, all in Ann Arbor, State of Michigan and 129 Awosting Road, Hewitt, State of New Jersey, all in the United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the folliowing statement:—

This invention relates to improvements in a knee joint prosthesis.

A substantially effective knee joint prosthesis is described in U.S. Patent 3,728,742 having spherical convex condyle and concave plateau surfaces on the femoral and tibial components. The spherical surfaces provide smooth flexure but do not completely duplicate all of the complex anatomical movements obtained in normal knee joint motion. An aim of the present invention is to provide a knee joint prosthesis having parallel convex condyle and concave plateau elements, which more exactly duplicates natural knee joint movement and provides a very high degree of intrinsic stability.

According to the invention, there is provided a knee joint prosthesis which, with reference to the orientation it would have in a standing recipient, comprises a ball and socket connection coupling a femoral component and a tibial component, said femoral component having a pair of spaced substantially parallel spheroidally curved condyle runners straddling a hollow central housing, said condyle runners having a front lower portion joining a rear upper portion having a smaller radius of curvature than said front lower portion, a slot in the bottom of said housing disposed substantially parallel to said runners, and a femoral attaching means in the top of said femoral component for attaching said femoral component to the femur of a recipient, the tibial component of said ball and socket connection having, on the bottom of a base, tibial connecting means for connecting said tibial component to the tibia of said recipient, and a pair of spheroidally curved spaced parallel concave sliding shoes on said base having upper surfaces substantially corresponding with the front lower portions of said condyle runners for intimately nesting said upper surfaces and front lower portions together when the joint is in the extended position, said ball and socket connection including a connecting rod rigidly fixed to and extending upwardly from said base of said tibial component, the ball portion of said ball and socket connection being disposed on the upper end of said connecting rod, said hollow central housing enclosing a segmented socket portion of said ball and socket connection, said ball portion being rotatably engaged in said socket portion, the smaller radius of curvature of said rear upper portions of said runners providing limited clearance between said shoes and said rear upper portions in flexed positions of said femoral and tibial components, said connecting rod being disposed in said slot which permits said connecting rod to pivot through the angle of flexure of the joint, wherein said segmented socket portion comprises a front insert and a rear insert, said hollow central housing having an inner cavity with an over-hanging edge on a portion of its mouth, said inserts being keyed with said overhanging edge whereby said inserts may be inserted into the cavity and removed therefrom through the cavity mouth clear of said overhanging edge in one rotational orientation and be retained within the cavity by said edge in another rotational orientation.

Preferably, the inserts are locked into place within the cavity by detent means in their retained orientation. In an embodiment the inserts are each provided with vertical slots which provide clearance for the connecting rod as the femoral component angularly moves between its extended and flexed positions relative to the tibial component. Preferably also, the vertical slot of the rear insert has a height that provides an edge against which the connecting rod

abuts to arrest the flexure movement of the femoral component relative to the tibial component.

Preferably, the arresting action of the edge is supplemented by an outward protrusion or thickening of the terminal ends of the rear upper portions of the condyle runners which are arranged to wedge against the rear ends of the shoes.

In order that the present invention will be more fully understood, it will now be described in conjunction with the accompanying drawings wherein similar reference characters refer to similar parts and in which:

Fig. 1 is a side view in elevation of an embodiment of this invention serving as the knee joint between a femur and tibia, which are shown in phantom outline;

Fig. 2 is a left elevational view of the embodiment shown in Fig. 1 showing the rear of the knee joint;

Fig. 3 is a right elevational view of the embodiment shown in Fig. 1 showing the front of the knee joint;

Fig. 4 is a side elevational view of the embodiment shown in Fig. 1 with the knee joint uexed in the sitting position;

Fig. 5 is an enlarged cross-sectional view taken through Fig. 2, along the line 5—5;

Fig. 6 is an enlarged cross-sectional view taken through Fig. 2 along the line 6—6;

Fig. 7 is a rear view in elevation of the tibial component of the embodiment shown in Figs. 1—5 with the ball of the connecting rod disposed within a segmented plastics socket of the femoral component, which is partly broken away in cross section;

Fig. 8 is a front view in elevation of the rear segment of the segmented plastics socket;

Fig. 9 is a front view in elevation of the front segment of the segmented plastics socket;

Fig. 10 is a bottom plan view of the tibial portion of the embodiment shown in Figs. 1—9;

Fig. 11 is a top plan view of a wrench for installing and removing the socket shown in Figs. 7—9; and

Fig. 12 is a side view in elevation of the wrench shown in Fig. 11.

In Figs. 1—3 and 5 is shown a knee joint prosthesis 10 in the extended and in the partially flexed position, respectively, in which the upper and lower portions of the leg represented by femur 12 and tibia 14 are in anatomical alignment with each other. Joint 10 includes a femoral component 16 and a tibial component 18 coupled by ball and socket connection 20. Femoral component 16 has a pair of spaced substantially parallel spheroidally curved condyle runners 22 straddling a hollow central housing 24.

Condyle runners 22 each have a front lower portion 26 having a relatively larger radius of curvature and a rear upper portion 28 having a relatively smaller radius of curvature. The radius of curvature of front lower portion 26 is, for example, twice as large as the radius of curvature of rear upper portion 28. Femural attaching stem 30 is attached to the top of hollow central housing 24 and is substantially of square cross-section with shallow depressions 32 in each of the sides for facilitating cementing and retention in the femur.

Ball and socket connection 20 in hollow housing 24 includes spherical ball 34 entrapped within a segmented plastics socket 36 including front half 36A and rear half 36B, later described in detail. Socket 36 is suitably made of a high molecular weight polymer such as high density polyethylene. All other portions of knee joint 10 are made of a non-corrosive metal having stable expansion and other physical characteristics, with the exception of shoes 38 which are also made of a high molecular weight polymer such as high density polyethylene. The metal portions are advantageously made of metal compatible with the human body such as Vitallium, the trademark of Howmedica Inc. for a cobaltchromium alloy, developed and used for cast partial and full dentures, and for internal applications by surgeons. When polished, it is exceedingly smooth and permanently lustrous. Its outstanding qualities are permanent inertness in relation to living tissues, and high resistance to corrosion.

Condyle runners 22 correspond to the condyle portions of a human knee joint and also have a transverse radius of curvature shown in Fig. 3 to make their surfaces substantially spheroidal. Transverse radius of curvature 40 shown in Fig. 3 is preferably substantially equal to the smaller radius of curvature of condyle runner upper rear portions 28.

Shoes 38 shown in Fig. 5 correspond to the plateau portions of the human knee and have a concave surface 42 shown in Fig. 5, which substantially correspond to the shape of lower condyle runner portions 26 to cause these portions to intimately nest with each other in the extended position shown in Fig. 1 and provide firm support for the extended leg. Shoes 38 have substantially the same transverse radius as curvature 40 shown in Fig. 3. This geometry helps provide the aforementioned stable nesting in the extended position, and provides an interference control of the rotation and wobbling movements facilitated by the ball 34 and socket 36.

Ball 34 is disposed on the top of a connecting rod 44, which is mounted on the top of a base 46 of tibial component 18. A regularly gouged tibial connecting stem 48 extends downwardly into tibia 14 from the bottom of base 46. Shoes 38 are mounted

in recesses 50 in the upper surface of base 46.

Fig. 4 shows the position of joint 10 when femoral component 16 is rotated to a horizontal position, such as when a person is in the sitting position. This engages the upper rear portions 28 of condyle runners 22 with shoes 38. The flexure motion is smoothly arrested by an outward protrusion or slight thickening of the terminal ends 52 of upper rear condyle portions 28 which wedge against the rear ends of shoes 38. This smoothly arrests the flexure movement without any clunking and simulates the normal knee action. The flexure movement of joint 10 is also arrested by the abutment of connecting rod 44 against this rear edge 64 of rear socket portion 36B.

The extending movement of joint 10 about axis 56 of ball and socket joint 20 is arrested by the nesting of lower larger radius of curvature portions 26 of condyle runners 22 within shoes 38. Smaller radius of curvature condyle portions 28 have an axis of rotation which passes through the ball center 56 in the position shown in Fig. 5. This allows the larger radius of curvature condyle runner portions 26 to firmly engage into the concave surfaces 42 within shoes 38 and thus provide secure abutment and firm support for each other in extension. During movement of joint 10 from the extended position shown in Fig. 1 to the flexed position shown in Fig. 4 through the intermediate position of Figure 5, smaller radius of curvature portions 28 of condyle runners 22 move slightly free of internal shoe surfaces 42 which thus allows a light wobbling or controlled play within the confines of shoes 38 until the bottoms of condyle runners 22 engage the outer edges of shoes 38 which limit such movement. This simulates the normal rotational inward and outward tilting or wobbling of a normal knee joint throughout the flexed positions and with more restraint as the joint is moved towards the extended position.

Figs. 7—10 show the manner in which segmented plastics socket halves 36A and 36B are disposed about ball 34 and inserted within cavity 60 in hollow central housing 24. Rear insert portion 36B has a slot 62 having a relatively lower outer dome 64 relative to higher outer dome 66 of slot 68 in front socket segment 36A. This provides for movement from the extended position shown in Fig. 1 to the flexed position shown in Fig. 4 and accordingly provides the necessary clearance for the relative angular movement of connecting rod 44. Connecting rod 44 is narrower than the width of slots 62 and 68 to insure non-interference with the play or wobbling action throughout the flexed orientation of knee joint 10.

Fig. 10 shows the bottom surface 70 of tibial base 46 serrated by spherical pits 72, which help cement base 46 to tibia 14.

Figs. 11 and 12 show wrench 74 having stem 76 connected to arcuate rod 78 upon which pins 80 are mounted. Pins 80 are inserted into holes 82 in the bottom edges 85 and 86 of rear and front socket segments 36B and 36A for rotating the segments about ball 34, for insertion into and removal from cavity 60 as shown in Fig. 6. Assembly socket segments 36A and B are accordingly inserted into cavity 60 in the position shown in Fig. 6 in which flat edge 84 of rear segment 36B clears overhanging edge 87 of cavity 60. After such insertion, rotation of segments 36A and B in the direction of arrow 88 locks the outer circumference 89 of socket segments 36A and 36B under overhanging edge 87 to lock the segments in place. The locked position is indexed and stabilized by the rotation of identation 90 in front segment 36A into alignment with detent projection 92 on the wall of cavity 60. Reverse rotation back to the position shown in Fig. 6 allows removal of ball and socket insert 20 from cavity 60.

Knee joint 10 has the following advantages:

1) *Ease of surgery*: A medical parapatellar incision allows exposure for a single transverse saw cut across the tibia approximately 1/2 cm. below the joint surface. The angled transverse saw cuts across the femur are then made. The medullary spaces are broached. Bone cement is placed in the femoral broached space and across the osteotomy site. The femoral component is inserted. The tibial component is similarly installed. The knee is flexed, the ball and socket insert snapped into place, the knee extended, and the wound closed.

2—3) *Versatility — Inherent Stability*: Knee joint 10 is an inherently stable prosthesis which enables treatment of joints lacking viable capsules and ligaments in addition to pathologic articular surfaces, both condylar and patellar. Few sizes are needed (three are foreseen).

4) *Range of Motion*: Design of runner shoe geometrics enables the motion characteristics desired. Flexion-extension from −5° to 100° is readily accomplished. Valgusvarus and rotational freedom is attained by the "sloppy" though carefully controlled interplay between runners and inserts. Runner shoe track sidewall camming action yields a non-impact but secure arrest of motion.

5) *Controlled Decceleration*: The camming action arrestment prevents "clunk" impact loadings at full extension (Fig. 1) and full flexion (Fig. 4).

6) *Materials*: All components are made of medically accepted metal and high density polyethylene.

7) *Load Bearing Areas*: The runner-track bearing areas are as large as currently available partial knee configurations. The ball-socket area is a significant additional increase in bearing surface over that of such configurations.

8) *Prosthesis-Bone Interface*: Only metal-cement-bone interfaces are used.

9) *Replacement of Failed Components*: The parts susceptible to wear (two tibial inserts and one socket insert) are readily replaced.

10) *Shear Forces*: High density polyethylene is not in contact with cement. Low frictional characteristics of high density polyethylene polished metal bearing surfaces minimize shear forces on both components.

11) *Salvage Possibilities*: A knee joint compression arthrodesis is possible as a salvage procedure.

12) In addition to the above, knee joint 10 looks like a knee to surgeon and patient alike, and its functional characteristics are similar to those of the normal knee.

WHAT WE CLAIM IS:—

1. A knee joint prosthesis which, with reference to the orientation it would have in a standing recipient, comprises a ball and socket connection coupling a femoral component and a tibial component, said femoral component having a pair of spaced substantially parallel spheroidally curved condyle runners straddling a hollow central housing, said condyle runners having a front lower portion joining a rear upper portion having a smaller radius of curvature than said front lower portion, a slot in the bottom of said housing disposed substantially parallel to said runners, and a femoral attaching means in the top of said femoral component for attaching said femoral component to the femur of a recipient, the tibial component of said ball and socket connection having, on the bottom of a base, tibial connecting means for connecting said tibial component to the tibia of said recipient, and a pair of spheroidally curved spaced parallel concave sliding shoes on said base having upper surfaces substantially corresponding with the front lower portions of said condyle runners for intimately nesting said upper surfaces and front lower portions together when the joint is in the extended position, said ball and socket connection including a connecting rod rigidly fixed to and extending upwardly from said base of said tibial component, the ball portion of said ball and socket connection being disposed on the upper end of said connecting rod, said hollow central housing enclosing a segmented socket portion of said ball and socket connection, said ball portion being rotatably engaged in said socket portion, the smaller radius of curvature of said rear upper portions of said runners providing limited clearance between said shoes and said rear upper portions in flexed positions of said femoral and tibial components, said connecting rod being disposed in said slot which permits said connecting rod to pivot through the angle of flexure of the joint, wherein said segmented socket portion comprises a front insert and a rear insert, said hollow central housing having an inner cavity with an over-hanging edge on a portion of its mouth, said inserts being keyed with said overhanging edge whereby said inserts may be inserted into the cavity and removed therefrom through the cavity mouth clear of said overhanging edge in one rotational orientation and be retained within the cavity by said edge in another rotational orientation.

2. A knee joint prosthesis according to claim 1, wherein the inserts are locked into place within the cavity by detent means in their retained orientation.

3. A knee joint prosthesis according to claim 1 or 2, wherein the inserts are each provided with vertical slots which provide clearance for the connecting rod as the femoral component angularly moves between its extended and flexed positions relative to the tibial component.

4. A knee joint prosthesis according to claim 3, wherein the vertical slot of the rear insert has a height that provides an edge against which the connecting rod abuts to arrest the flexure movement of the femoral component relative to the tibial component.

5. A knee joint prosthesis according to claim 4, wherein the arresting action of the edge is supplemented by an outward protrusion or thickening of the terminal ends of the rear upper portions of the condyle runners which are arranged to wedge against the rear ends of the shoes.

6. A knee joint prosthesis, constructed and arranged substantially as hereinbefore described with reference to and as illustrated in Figs. 1 to 10 of the accompanying drawings.

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Sheet 1

Fig.1.

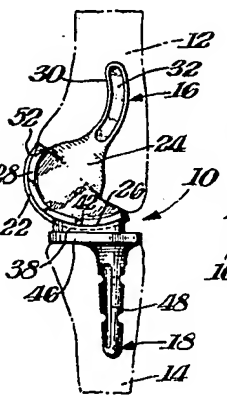


Fig.2.

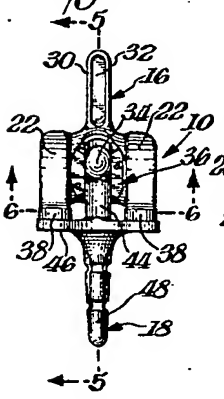
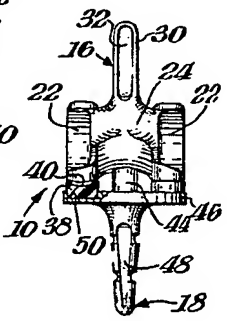


Fig.3.



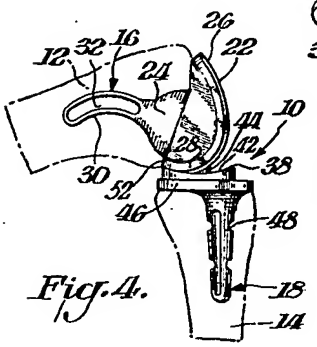
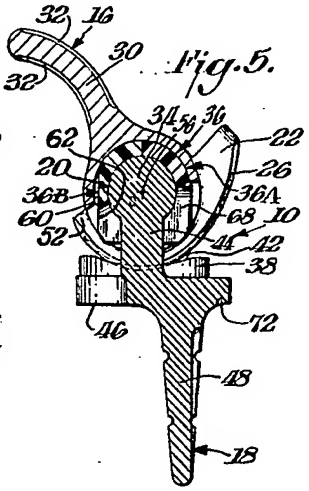


Fig.4.

Fig.5.



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Sheet 2

Fig.7.

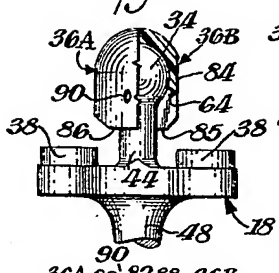


Fig.8.

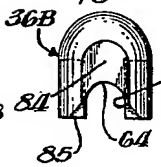
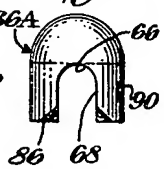


Fig.9.



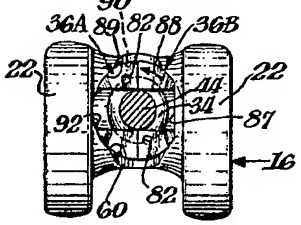


Fig.10.

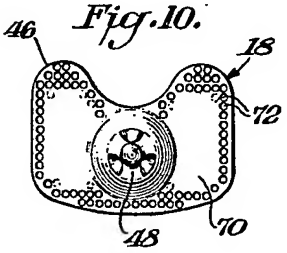
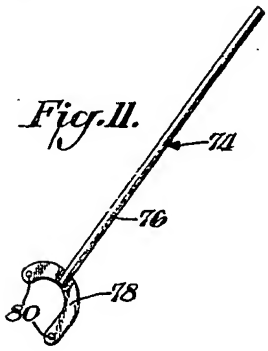


Fig.6.

Fig.11.



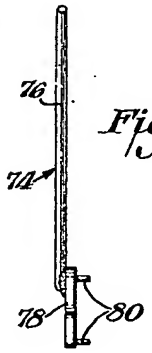


Fig.12.